GALCET2K: A LINE-TRANSECT SURVEY FOR CETACEANS ACROSS AN ENVIRONMENTAL GRADIENT OFF THE GALÁPAGOS ISLANDS, 5-19 APRIL 2000

Final Report

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Introduction

GalCet2K was a survey of cetacean abundance in an area with a strong environmental gradient on the western side of the Galápagos Archipelago. The survey took place between 5-19 April 2000, aboard R/V *Odyssey*. The main objective of the study was to determine the influence of spatial environmental variability on cetacean occurrence patterns. Considering that mesoscale oceanographic processes appear to be important in delineating cetacean habitats, it is expected that the results from this study will improve our understanding of the coupling between cetaceans and their environment at this scale (i.e., a few tens to a few hundreds of kilometers).

Survey design

The area selected for the survey was a 3°x2° box approximately 74,166 km^2, designed to encompass the cool, productive waters to the west of the islands, where the Equatorial Undercurrent upwells, as well as the warm, oligotrophic waters to the north of the Equatorial Front (located at ~1°N). The original boundaries of this box were set to extend from 92-94°W of longitude and 2°N-1°S of latitude, based on the long-term sea-surface temperature (SST) climatology for the Autumn months (March-May), as illustrated in Figure 1.

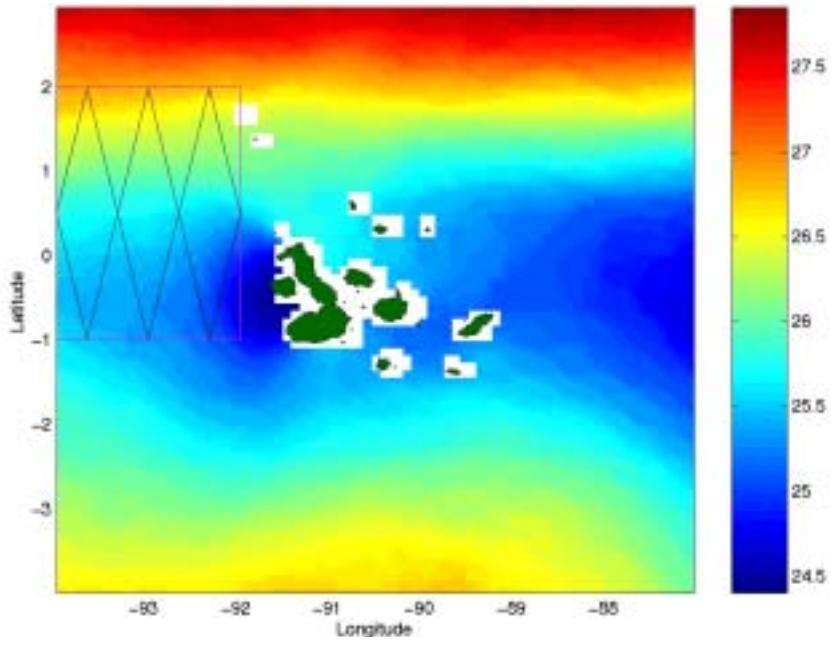

Figure 1. Original survey area and tracklines, superimposed on the long-term SST (°C) Autumn climatology (the NASA Seasonal to Interannual Prediction Project (NSIPP) 'Pathfinder+Erosion Monthly SST Climatology' product uses the 9.28-km AVHRR Pathfinder dataset for the years 1985-1997).

The survey tracklines were spaced regularly following a north-south zigzag pattern inside the study area. There were 12 trackline segments, each one being 90 n.mi long (~167 km), for a total of 1,080 n.mi (~2,000 km) of track. Water column properties (temperature, salinity, density, and phytoplankton standing stock) were measured at more or less regularly spaced stations along the trackline, using a CTD instrument (SBE 25 Sealogger, Sea-Bird Electronics, Inc.) with an attached miniature fluorometer (WETStar, WET Labs, Inc.). CTD casts were performed to a maximum depth of 150 m. Sea-surface temperature was measured along the track with a temperature sensor (Davis Weather Monitor II, Davis Instruments, Corp.) mounted through the ship's hull, at a sampling rate of eight minutes. Biological samples were opportunistically collected at the surface (e.g., zooplankton, squid, fish) with a dip-net or a bucket for identification and further study.

Cetacean survey methods

The R/V *Odyssey* was utilized as the survey platform. The *Odyssey* is a 28-m sailboat (a ketch) owned and operated by the Ocean Alliance, a non-profit whale research organization based in Lincoln, MA. Cetacean surveying was conducted from an observation platform located 5.6 m above sea level, with a maximum sighting distance to the horizon of 4.56 n.mi. (8.45 km), as shown in Figure 2. Surveying effort was carried out at a nominal cruising speed of 8.5 knots (15.74 km/h), employing standard line-transect techniques. Experienced cetacean observers maintained a visual watch during daylight hours (0600-1800 h), using 7x binoculars to scan the area 180° forward to the ship to the horizon. An observer team of four people rotated every hour through three stations: port observer, starboard observer, and data recorder.

Figure 2. Research vessel *Odyssey* with the observation platform on top of the pilothouse. Inset shows observers manning the port and starboard stations. The data recorder station was located inside the pilothouse.

For each cetacean sighting, bearing (angle from the trackline, measured with an azimuth ring) and distance (calculated using the calibrated reticle scale in the binoculars) were recorded. Weather conditions related to sightability (sea state, swell, meteorological conditions) and navigation data were also recorded. Cetacean sightings within one nautical mile from the trackline were approached to obtain species identification and to estimate school size. All data were entered into a laptop computer running the software WinCruz v. 5.2.1. (written by Robert Holland, Marine Mammal Division, NMFS/Southwest Fisheries Science Center). Data on seabird, turtles and sharks seen at the surface were also regularly collected as part of the survey protocol.

Results

La Niña (cooler than normal) conditions, that initially developed in late 1998 in the eastern tropical Pacific, prevailed well into the austral Autumn months of the year 2000. Near-real-time satellite images of sea-surface temperature and of ocean color (surface phytoplankton distribution) for the study area were received on a regular basis via the ship's e-mail system (images were sent by Gene C. Feldman, NASA/Goddard Space Flight Center). Examination of these images (Figure 3) indicated that the spatial configuration of the environmental gradient in early April 2000 differed from the climatology. Therefore, five days into the survey it was decided to move the meridional boundaries of the box to 91°20'-93°20'W (i.e., closer to the islands), to best cover the features of interest.

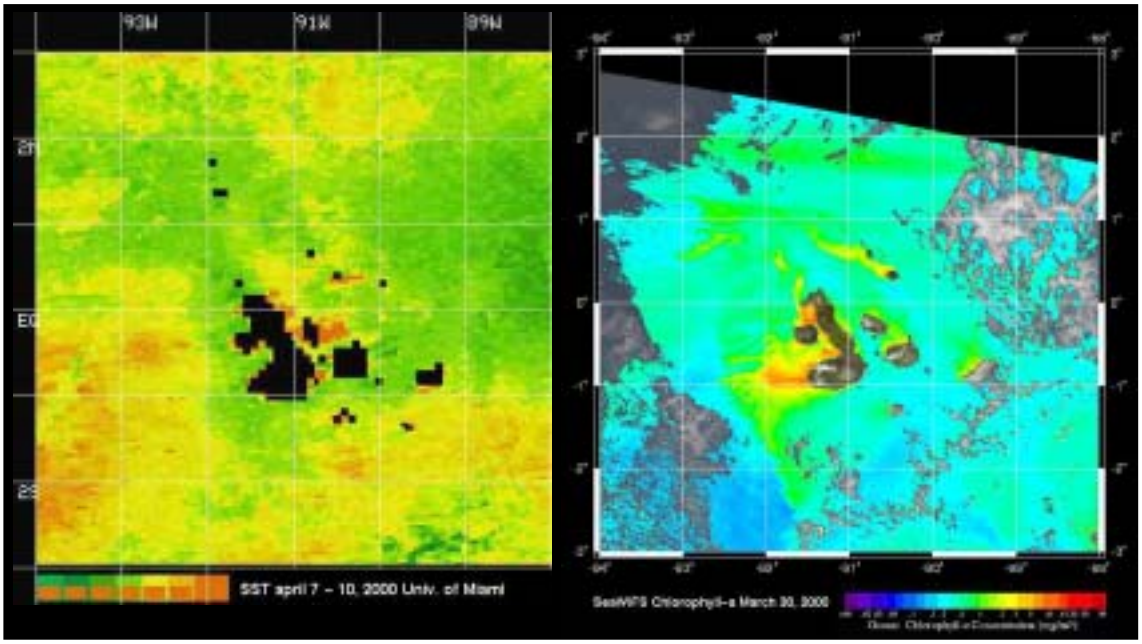

Figure 3. Satellite-measured sea-surface temperature and phytoplankton pigment concentrations around the Galápagos Islands during the GalCet2K survey (imagery courtesy of Gene C. Feldman, NASA/GSFC).

Search effort for cetaceans totaled 1,712.86 km of trackline for the 15 days of the survey (Figure 4). Daily search effort averaged 114.19 km (SD = 31.14 km) of trackline. On average, two CTD casts were completed per day, for a total of 32 casts. Figure 4 shows the locations where CTD stations were occupied. Areas with sparse coverage (i.e., the northwest sector of the survey area) are due to unfavorable weather conditions or other factors that made it impossible to lower the instrument at the time. Interpolated vertical and horizontal fields for temperature, salinity, density, and phytoplankton fluorescence will be estimated from these data using an objective analysis scheme. Sea-surface temperature was recorded on 885 occasions along the track (daily average = 59 records, SD = 28.14 records). Figure 5 shows the distribution of sea-surface temperature along the survey track.

A total of 195 cetacean sightings were made during the 15 days of the survey. Of these, 135 were identified to the lowest possible taxonomic level (involving 12 species or genera) and 60 were unidentified (Table 1). Figures 6-8 show the sighting locations for the more abundant species. The number of sightings made during on-effort segments of the trackline was 175. Thus, average encounter rates were 11.67 cetacean schools per day (SD = 4.01) or about 0.10 cetacean schools per kilometer of trackline. Relative abundance will be estimated for the most representative species using distance sampling methods.

Table 1. Cetacean sightings collected during GalCet2K, 5-19 April 2000.

Species	**Pure schools**	**Mixed schools**	**Total***
Dephinus delphis	65	7	72
Stenella coeruleoalba	19	6	25
Globicephala macrorhynchus	7	2	9
Tursiops truncatus	4	3	7
Stenella longirostris	0	6	6
Stenella attenuata	0	4	4
Physeter macrocephalus	11	0	11
Balaenoptera sp.	4	0	4
Ziphius cavirostris	3	0	3
Mesoplodon sp.	3	0	3
Kogia sp.	3	0	3
Orcinus orca	1	0	1
Unidentified	N/A	N/A	60

*The total in this column (n = 208) is higher than the total number of sightings (n = 195) because mixed schools are counted twice (once for each sighting category).

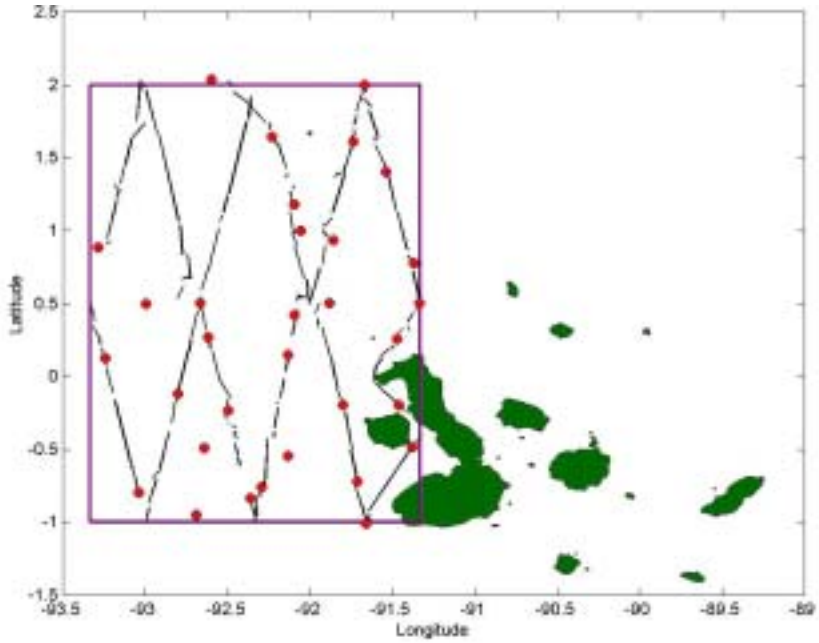

Figure 4. On-effort segments of trackline and location of CTD stations (red dots).

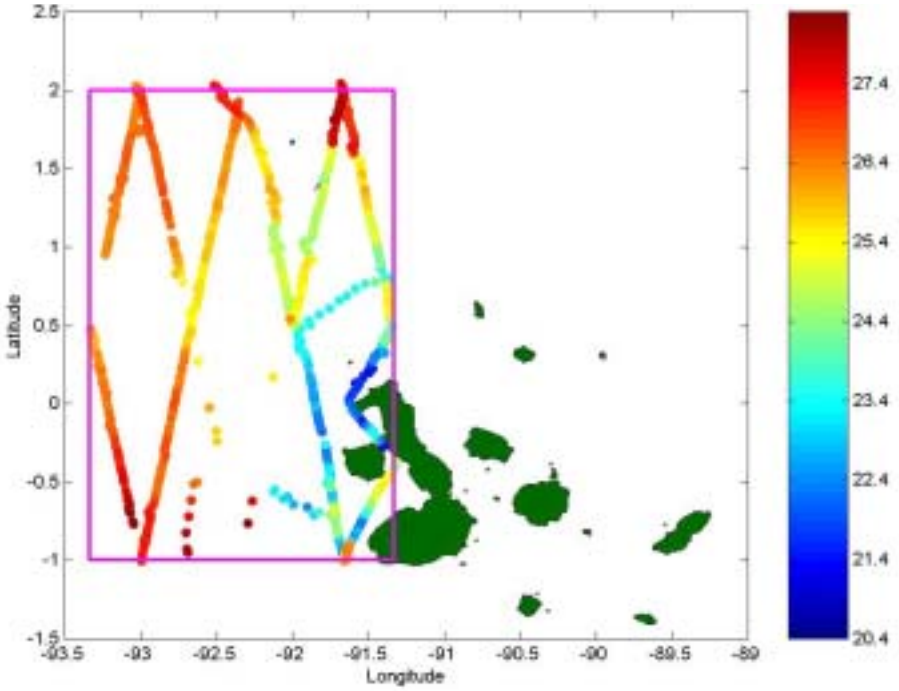

Figure 5. Sea-surface temperature (°C), as measured along the survey track.

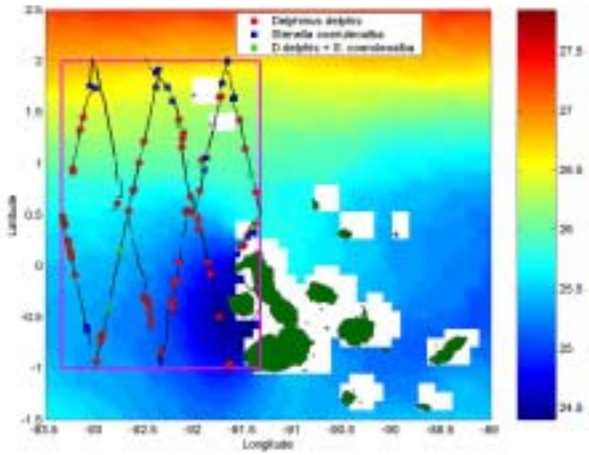

Figure 6. Sighting locations for *Delphinus delphis* and *Stenella coeruleoalba*, and the long-term SST Autumn climatology.

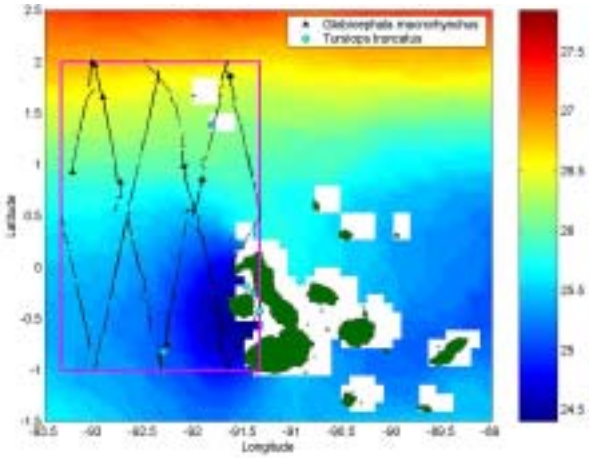

Figure 7. Sighting locations for *Globicephala macrorhynchus* and *Tursiops truncatus*, and the long-term SST Autumn climatology.

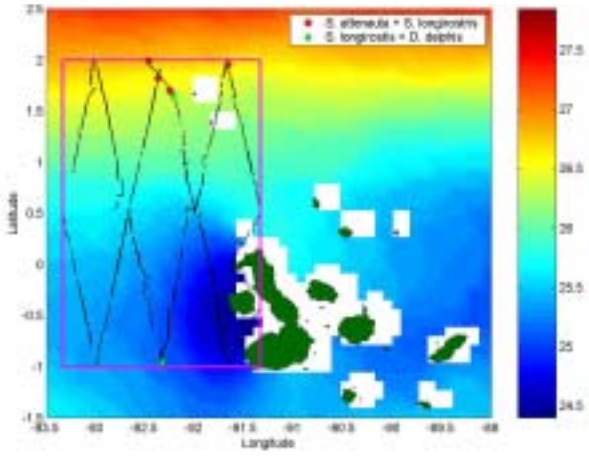

Figure 8. Sighting locations for *Stenella attenuata* and *S. longirostris*, and the long-term SST Autumn climatology.

Biological samples collected on an opportunistic basis included squid beaks, mesopelagic fish and zooplankton. Samples were frozen or fixed in alcohol. Table 2 presents information for the zooplankton samples. The squid (including a large individual with a 90.3-cm mantle length) and the mesopelagic fish remain to be identified. These samples were collected for general documentation purposes, but they will also be useful in studies of potential prey for cetaceans.

Table 2. List of zooplankton samples collected and preliminary identification (provided by Jaime Gómez-Guitérrez and Charles B. Miller, Oregon State University).

Date	**Location**	**Identification/notes**
17 April 2000	0°30.7 N, 91°56.7 W	large amphipods
2 May 2000	0°33.53 N, 90°53.1 W	Bioluminescent sample Eupahusiids: *Euphausia distinguenda* *Euphausia diomedeae* Copepods: *Pleuromamma* sp. *Pleuromamma ziphius* *Eucalanus* sp., *Euchaeta* sp. *Calanus minor* or *Undunila* sp. large chaetognaths (arrow worms) small amphipods
6 May 2000	0°35.06 S, 90°08.8 W	Red patches at surface, SE of Gordon Rocks. Identified as swarms of larvae (calyptopis II and III) of the euphausiid *Nyctiphanes simplex.*

Concluding remark

The area selected for the GalCet2K survey successfully captured the environmental gradient of interest (as is evident in Figures 3 and 5). The majority of the cetacean search effort was conducted under calm sea states, a desirable condition when making estimates of abundance. The dominant species in the study area were the common dolphin (*Delphinus delphis*) and the striped dolphin (*Stenella coeruleoalba*), both of which are typically found in areas modified by upwelling. Further, these two species appear to be partitioning their habitat at the scale of interest (a few tens to a few hundreds of kilometers). This aspect will receive particular attention when the data are analyzed. The survey also captured the transition into the warm, oligotrophic waters to the north of the Equatorial Front (along the northern edge of the survey box), where spotted dolphins (*Stenella attenuata*) and spinner dolphins (*Stenella longirostris*) begin to become the dominant species. Forthcoming analyses of the data gathered during this survey will improve our understanding of cetacean-habitat relationships at the mesoscale.

Acknowledgements

This study was part of a larger project on sperm whale toxicology, genetics, acoustics and population structure by the Ocean Alliance. The activities reported here were conducted under authorization from the Galápagos National Park (Proyecto No. PC-32-00 of 11 February 2000, with Alcance a la autorizacion original of 13 March 2000) and from the Dirección General de la Marina Mercante y del Litoral (Autógrafo: Acuerdo No. 018/00 of 27 March 2000), to Roger Payne, of the Ocean Alliance. Poly Robayo, Jenni Thompson and Edwin Yánez of the Charles Darwin Research Station provided invaluable logistic support. The port captains of Santa Cruz and Seymour islands kindly processed our *zarpe* paperwork. TAME airlines provided discounted air travel between the Galápagos and continental Ecuador.

This study would not have been possible without the able help of Lisa Baraff, Rebecca Clark and Karin Forney, who as observers endured the intensive rotations through the binoculars under the relentless equatorial sun. Karin Forney, in particular, made sure the line-transect data was collected with the highest standards. To them I express my deepest gratitude. My heartfelt appreciation also goes to the crew of the R/V *Odyssey*: Joshua Jones, Genevieve Johnson, Christopher Johnson, Robert Wallace, Alison Walker and Daniel McBride for ensuring a successful operation.

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